

1 Specification

2  
3 INTELLIGENT CAMERA FLASH SYSTEM

4  
5 BACKGROUND OF THE INVENTION

6  
7 Field of the Invention

8 The present invention relates generally to electronic  
9 digital cameras, and more particularly to a digital camera using  
10 a pre-flash in combination with digital camera image acquisition  
11 apparatus and a processor for creating a histogram to determine  
12 an optimum flash power controlled through calculation of flash  
13 capacitor voltage.

14  
15 Brief Description of the Prior Art

16 Prior art cameras have used many different techniques to  
17 achieve optimum exposure, from hand held light meters to built  
18 in automatic exposure systems with flash. One method of  
19 controlling exposure is based on "through the lens" flash  
20 control in which the flash is terminated when sufficient light  
21 is collected by a photo receptor in the camera. Another method  
22 uses an infrared photo diode to measure the light. The  
23 advantage of using infrared is that in the infrared zone, light  
24 is more evenly reflective as a function of color in the visible  
25 spectrum. These methods are all based on an average  
26 (integration) over the entire image, and are not able to  
27 separate out important image areas for priority in setting the  
28 amount of light for exposure. For example, a combination of a  
29 close image and a distant background will result in a "washed  
30 out" foreground. Since primary subjects are often in the  
31 foreground, this is a serious problem in automatic exposure  
32 systems. These exposure control systems also require a very  
33 fast electronic switching device for a fast flash and a separate  
34 photo receptor which add complexity and cost to the system. The  
35 infrared receptor also has a problem in that the light measured

1 is only a monochromatic estimation of the scenery. This  
2 estimation may be close in some cases, but in others, it  
3 accentuates the problem of film/CCD metamerism, a condition  
4 where different wavelengths in a scene are improperly recorded.

5 In Coltman et al., U.S. Patent No. 4,998,128 the  
6 reflectivity of a subject is determined by pulsing a flash unit  
7 for predetermined short period of time. The light is detected  
8 by both visible and infrared light detectors, the outputs of  
9 which are integrated and used to select an optimum aperture and  
10 speed setting for taking the picture. In Taylor, U.S. Patent  
11 No. 4,066,884 an adjustable filter is used to vary the light  
12 intensity from an electronic flash unit, the degree of  
13 adjustment being empirically determined for a particular type of  
14 camera, in this case cameras designed for use with explosive  
15 flashbulbs which have relatively long duration of light  
16 intensity. The problem with the electronic flash unit when used  
17 with cameras having automatic exposure adjustment is that the  
18 time duration of the electronic flash is too short for the  
19 automatic exposure system to work. In Winter, U.S. Patent No.  
20 4,549,801, an electrically operated flash camera employs an  
21 infrared flash reflected light signal stored in a single memory  
22 storage to control focus and aperture. In Ishida, U.S. Patent  
23 No. 4,256,995, an electronic flash is disclosed which is capable  
24 of emitting light for a longer duration of time so as to allow  
25 automatic exposure control camera systems to function.  
26 Kabayashi et al., U.S. Patent No. 4,717,934 discloses a flash  
27 used prior to image acquisition to determine the amount of flash  
28 required for an adequate exposure. This is done by detecting  
29 and integrating light radiated directly from the flash, and  
30 integrating the reflected light from the object. The flash  
31 power is provided by a separate capacitor from the capacitor  
32 used for the main flash.

33 In Coltman, the pre-flash system functions independently  
34 from the camera image acquisition apparatus, depending on a  
35 predetermined look up table. The accuracy of this method is

1 limited to the exactness of the correlation between the look up  
2 table and the actual setting. The mechanical adjustment device  
3 of Taylor for control of the flash intensity is dependent on the  
4 skill of the operator in knowing where to set the flash cover.  
5 In Winter, the burden of adjusting for exposure is placed  
6 entirely on the camera aperture and shutter speed. No attempt  
7 is made to control the amount of flash. The device of Ishida  
8 similarly does not use control of the flash time as an aid in  
9 achieving proper exposure but simply provides a flash of long  
10 duration, allowing conventional camera automatic exposure  
11 systems to function as if the lighting were ambient. This  
12 system would consume larger amounts of flash power than what  
13 would otherwise be required for proper exposure. The device of  
14 Kabayashi requires a separate capacitor for pre-flashing, which  
15 involves extra cost and space.

16 It is apparent from the above references that an improved  
17 camera is desirable, that conserves flash power and minimizes  
18 cost and space. Also, an improved camera would provide a method  
19 for evaluating light from different parts of an image to  
20 determine optimum exposure of particularly selected areas, this  
21 being a particular problem when objects are at various distances  
22 from the camera and when they are in contrast to each other.  
23 Such a camera would be a significant improvement over the prior  
24 art.

25

26 SUMMARY OF THE INVENTION

27 It is therefore an object of the present invention to  
28 provide an improved digital camera having provision for  
29 determining optimum flash energy for illumination of a selected  
30 area of an image.

31 It is a further object of the present invention to provide  
32 an improved digital camera using reduced energy flash  
33 illumination to determine optimum full flash energy.

34 It is another object of the present invention to provide an  
35 improved digital camera having a flash system providing a series

1 of lower power flashes prior to a final flash utilizing a single  
2 capacitor and providing for optimum use of flash energy.

3 It is another object of the present invention to provide an  
4 improved digital camera that uses the image acquisition  
5 apparatus to determine optimum camera exposure parameters from  
6 a low energy flash prior to a final flash.

7 It is a further object of the present invention to provide  
8 a camera having a method of estimating an acquired image from  
9 data collected from low energy pre-flashes.

10 It is a still further object of the present invention to  
11 provide a camera that determines flash exposure based on center  
12 weight subsampling.

13 It is another object of the present invention to provide a  
14 method for determining the energy of sequential flashes  
15 (strokes) based on the discharge curve of the flash capacitor in  
16 a digital camera.

17 It is a further object of the present invention to provide  
18 a method of determining flash exposure based on samplings of an  
19 image luminous histogram.

20 Briefly, a preferred embodiment of the present invention  
21 includes an intelligent flash system for a digital camera having  
22 components including an image optical pickup, an interface  
23 circuit, a flash unit and a processor. Upon activation of the  
24 camera, ambient lighting conditions are evaluated and if flash  
25 energy is required, a first low energy flash is radiated, the  
26 reflected light received by the optical pickup having a  
27 multiplicity of pixels, and the output of the pixels converted  
28 to image intensity data by the interface circuit. The processor  
29 samples the image intensity data, weighing the center image area  
30 more heavily, and creates a histogram plot of quantity of pixels  
31 v.s. intensity, and separates the plot into a bar graph from  
32 which a determination of exposure is obtained. The histogram is  
33 then used to calculate a multiplicative scaling factor used to  
34 multiply the first flash energy as an estimate of a final flash  
35 energy for correct exposure. Conditions of extreme over and

1 under exposure result in the activation of a second flash at an  
2 adjusted energy level. The image data of the second flash is  
3 then analyzed and the exposure compared with the result of the  
4 first flash. A final determination of flash energy is then made  
5 based upon the results.

6 An advantage of the present invention is the provision of  
7 a flash system for a digital camera that provides optimum flash  
8 energy.

9 A further advantage of the present invention is that it  
10 provides a flash system that uses reduced energy flashes in the  
11 determination of exposure, thus conserving total flash energy.

12 Another advantage of the present invention is the provision  
13 of a flash system that conserves flash energy and operates from  
14 a single flash capacitor.

15 A further advantage of the present invention is the use of  
16 the image acquisition optics to determine exposure, thus  
17 providing increased accuracy and a reduced parts cost.

18 It is a further advantage of the present invention to  
19 provide a flash system that determines exposure based on center  
20 weight sampling, giving greater importance in exposure  
21 determination to a more important area of the image.

#### 22 23 IN THE DRAWINGS

24 Fig. 1 shows a block diagram of a digital camera according  
25 to the present invention;

26 Fig. 2 is an overall block diagram of the intelligent flash  
27 system;

28 Fig. 3 is a block diagram showing further details of the  
29 method of achieving correct exposure;

30 Fig. 4A is a sample image area illustrating the selection  
31 of a selection of a preferred object area;

32 -Fig. 4B illustrates the weighted sampling of the preferred  
33 object area of Fig. 3A;

34 Fig. 5 is a simplified array of pixel intensities;

1 Fig. 6A is a simplified histogram and bar graph based on  
2 the image intensity data of Fig.4;

3 Fig. 6B is a table of the quantities of pixels and their  
4 intensities before and after scaling;

5 Fig. 7 is a block diagram illustrating the method of  
6 exposure determination using the bar graph;

7 Fig. 8 is a more realistic histogram before and after  
8 scaling;

9 Fig. 9 is a block diagram showing the method of determining  
10 a scaling factor;

11 Fig. 10 is a block diagram illustrating the determination  
12 of flash capacitor cutoff voltage;

13 Fig. 11 is a schematic of a flash circuit; and

14 Fig. 12 is a detailed block diagram showing the analysis of  
15 the image resulting from activation of a second flash.

16

#### 17 DESCRIPTION OF THE PREFERRED EMBODIMENT

18 A typical camera system in which the method and apparatus  
19 of the present invention is employed is shown in Fig. 1, wherein  
20 a digital camera 10 is illustrated having a multiprocessor 12  
21 activated by shutter activator 14 through line 16, and  
22 communicating through bus 18 with image interface circuit 20.  
23 The multiprocessor further communicates with memory 22 through  
24 bus 24 and interconnects with the flash unit 26 through bus 28.  
25 Image optical pick-up 30 is interconnected to the image  
26 interface circuit 20 through bus 32. A power supply 34 is shown  
27 for providing electrical energy to the various circuit  
28 components through lines not shown.

29 In response to the shutter activator 14, light 36 from an  
30 image to be recorded is received by the image optical pick-up 30  
31 and sent via bus 32 to the image interface circuit 20 which  
32 communicates with the pick-up 30 and processor 12 to provide  
33 digital image intensity data corresponding to the light 36.  
34 Further details of the pick-up 30 and circuit 20 are not  
35 necessary for an understanding of the present invention. Those

1 skilled in the art of digital cameras will know how to fabricate  
2 the light to digital data apparatus.

3 According to Fig. 2, a user can select (block 38) one of  
4 two modes, including an AUTO MODE (block 40) or a MANDATORY  
5 FLASH MODE (block 42). In either of the two modes, Auto or  
6 Mandatory Flash, the processor 12 is configured to respond to  
7 the activator 14 by sampling and analyzing the ambient light  
8 (blocks 44 and 46) to determine if it is adequate. In the Auto  
9 Mode, if the ambient light is found (block 48) to be adequate,  
10 the picture is taken without a flash (block 50). If the ambient  
11 light is not adequate and a flash is needed (52) the camera  
12 parameters (block 54) are set for what is defined as a "full  
13 flash mode" at which point the flash is adjusted for optimum  
14 exposure and the picture is taken (block 56). This process  
15 includes a series of one or more flashes applied to determine an  
16 optimum flash energy for proper exposure. The first flash is  
17 preset at a lower energy generally considered to result in  
18 "under" exposure. If the light from the first flash is adequate  
19 for an analysis, the image is analyzed and an estimate of a  
20 proper flash energy for a correct exposure is made and the  
21 picture is taken at this flash energy. If the light from the  
22 first flash is not sufficient for an analysis, a second flash is  
23 activated at a higher energy level. The preferred embodiment  
24 provides for a maximum of two flashes prior to a flash activated  
25 to take a picture. Alternate embodiments however can use any  
26 number of flashes prior to the final flash. When sufficient  
27 light for an analysis is provided by a flash, the processor 12  
28 scales the flash energy level to determine an estimated flash  
29 energy level for correct exposure and the camera takes the  
30 picture at this energy level.

31 In the preferred embodiment, if the second flash energy  
32 level is insufficient for an analysis, i.e. resulting in either  
33 extreme under or over exposure, no further analysis is done.  
34 The picture is then taken (block 58) at a minimum flash energy  
35 level if the second flash caused extreme over exposure or at a

1 maximum flash energy level if the result of the second flash was  
2 extreme under exposure.

3 The mandatory flash mode 42 results in the use of a flash  
4 regardless of the ambient lighting conditions, the purpose being  
5 to use the flash to fill shadows, such as on a subject person's  
6 face caused by bright sunlight. If the evaluation of ambient  
7 light (46) results in a determination (60) that a flash is  
8 needed (62), the camera parameters are set (54) as described  
9 above and the process continues according to the operations  
10 defined for blocks 56 and 58. If the ambient light is adequate,  
11 camera parameters are set 66 to reduce the ambient light input  
12 to the camera. The parameter adjustments in this case could  
13 include an increase in speed and/or a reduction in the camera  
14 aperture. The correct flash power is then determined and the  
15 picture is taken as explained above according to the operations  
16 associated with blocks 56 and 58.

17 The deliberate use of a low energy first flash is for the  
18 purpose of conserving flash capacitor energy so that the flash  
19 capacitor will subsequently have enough energy for a proper  
20 final flash without recharging. This method saves energy and  
21 eliminates the need for a separate flash capacitor for the  
22 flashes prior to the final flash.

23 Referring again to Fig. 1, the light 36 from the flash is  
24 reflected from an object, received by the pick-up 30 and  
25 converted to a multiplicity of analog signals, each  
26 corresponding to one pixel in an array. These analog signals  
27 are then processed into digital image intensity data by the  
28 circuit 20 and sent to the processor 12. This process of  
29 conversion of the light to image intensity data will be termed  
30 "grabbing the image" in the following text.

31 A more detailed description of the process of analyzing the  
32 image to determine exposure and a proper final flash will now be  
33 given. This description is somewhat complicated in the fact  
34 that the process is generally applicable to the two sources of  
35 light, i.e. from ambient or other secondary light and from a



1 flash, as indicated in blocks 44, 46 and 56. In order to avoid  
2 having to repeat a lengthy description, the following analysis  
3 will generally apply to both situations, with emphasis on the  
4 use of flash energy. The differences will be explained as the  
5 description proceeds.

6 In general, the camera 10 responds to the low energy first  
7 flash, or to a first ambient light sample by grabbing a first  
8 image (or first ambient image to distinguish the use of ambient  
9 light) and creating first image intensity (or first ambient  
10 image intensity) data. The processor 12 then constructs a first  
11 histogram and first bar graph from sampled first image intensity  
12 data, and from an analysis of this data determines a first  
13 degree of exposure, i.e. whether the object needs more or less  
14 light or whether the exposure is correct. In the above, the  
15 terminology generally also applies to an ambient/secondary light  
16 source. The terminology can be distinguished from the use of  
17 flash energy by replacing the terms first histogram, first bar  
18 graph and first degree of exposure with first ambient histogram,  
19 first ambient bar graph and first ambient degree of exposure.  
20 These distinctions will now be implied in the following  
21 descriptions without repetitiously making note of them.

22 If the amount of light (first degree of exposure) is  
23 correct, a second flash or sampling is bypassed and the first  
24 flash energy level (or camera parameters for ambient light) is  
25 used to take the picture. In the case of ambient light (blocks  
26 44 or 46), an automatic adjustment of camera parameters (speed,  
27 F-stop) would be made if the degree of exposure were not  
28 adequate. If the exposure is adequate, the picture is taken  
29 with ambient light and original parameters. If the exposure is  
30 not correct, but a meaningful histogram was created in the  
31 analysis, i.e., if the image was not greatly over or under  
32 exposed, a scaling procedure is performed on the sampled first  
33 image intensity data. This scaling procedure is performed by  
34 the processor by finding a first scaling factor to the first  
35 sampled intensity data so as to cause a predetermined percentage

1 (.5% preferred) of the pixels to be above the saturation value  
2 of the image optical pickup (preferably a CCD). This scaling is  
3 accomplished by multiplying the sampled first image intensity  
4 data by the first scaling factor and reconstructing and re-  
5 analyzing the histogram to determine the number of pixels with  
6 intensities exceeding the saturation value. Upon finding the  
7 proper scaling factor in the case when the camera is analyzing  
8 an image from a flash, the processor uses this factor as an  
9 energy scaling factor, by which to multiply the first flash  
10 energy level to obtain an estimated correct final flash energy  
11 level. The picture is then taken with this estimated final  
12 flash energy. If the light source is ambient with no flash, the  
13 scaling factor is used with a look-up table or as an appropriate  
14 factor to determine an adjusted set of camera parameters. If  
15 the result from ambient light is a condition of extreme under  
16 exposure to such an extent that no camera speed or aperture  
17 adjustment will correct it, the camera automatically shifts to  
18 the full flash mode (block 54) and the above process is  
19 activated as described in relation to the use of a first and  
20 second flash.

1 In either the case of ambient or flash light sources, the  
2 above described scaling is not performed if the degree of  
3 exposure is extremely under exposed (low clipping) or extremely  
4 over exposed (high clipping), since a meaningful histogram  
5 cannot then be prepared. If a meaningful histogram is not  
6 obtained from the first flash, due to either extreme under  
7 exposure (low clipping) or extreme over exposure (high  
8 clipping), a second flash at a second flash energy level is  
9 activated, the second flash energy level being at an adjusted  
10 fraction of the first flash. If the first degree of exposure is  
11 extremely under exposed (low clipping), the second flash energy  
12 level is adjusted to a greater energy level. If the first  
13 degree of exposure is extremely over exposed (high clipping),  
14 the second flash energy level is adjusted to a lower energy  
15 level. A second image of the object is then grabbed, and second

1 image intensity data is created from which sampled second image  
2 intensity data is taken and a second histogram and second bar  
3 graph are created therefrom. The second histogram and second  
4 bar graph are then analyzed and a second degree of exposure  
5 determined. If high or low clipping are still occurring, the  
6 flash energy is minimized or maximized respectively and a  
7 picture is taken. If the exposure is correct, the flash is  
8 again activated at the second flash energy level to take the  
9 picture. In the case of under or over exposure, i.e., moderate  
10 under or over exposure not resulting in clipping, a second  
11 scaling factor is determined and used as a multiplicative  
12 scaling factor on the second flash energy to determine an  
13 estimated correct final flash energy. The use of the term  
14 "under exposure" and "over exposure" in the following text will  
15 generally indicate moderate "over" or "under" exposure, rather  
16 than extreme under or over exposure which will be alternatively  
17 termed low and high clipping. The above description using a  
18 maximum of two flashes prior to a final flash is the preferred  
19 embodiment, however, alternate embodiments include any number of  
20 flashes prior to a final flash and are included in the  
21 invention.

22 The operation described in Fig. 2 can be more fully  
23 understood through reference to Fig. 3. The blocks 68-88  
24 included in block 90 give added detail to the operation of  
25 blocks 44-48, and 52-66 in Fig. 2. This determination of  
26 exposure in blocks 44 and 46 of Fig. 2 uses ambient light as the  
27 light sources. Block 56 uses a flash. In Fig. 3, block 90 more  
28 fully describes the activity of determining the exposure. Block  
29 68 indicates the activation of the light source, which is either  
30 a flash or a sampling of ambient light.

31 The image is then grabbed (block 70) i.e., detected by the  
32 optical pick-up 30 (Fig. 1) and processed by the interface  
33 circuit 20 to digital image intensity data. The image intensity  
34 data is then analyzed to determine a degree of exposure. This  
35 analysis involves the following operations in blocks 71 and 72

1 including sampling of the image intensity data in a selective  
2 manner (block 71) in order to weigh more heavily the data  
3 representing the primary object area. This area is usually  
4 considered to be near the center of the image, and such sampling  
5 is to be considered part of the preferred embodiment; however,  
6 the processor 12 could be programmed to weigh other areas more  
7 heavily and they are included in the spirit of the invention.

8 The sampled image data is then analyzed to determine the  
9 exposure (block 72), and the activity is directed accordingly.  
10 If the condition is extreme overexposure, resulting in high  
11 clipping where the large majority of pixels are at the high end  
12 of the intensity range, the process is directed to block 74. If  
13 the condition is extremely under exposed, the process continues  
14 in block 76. Simple over or under exposure not resulting in  
15 clipping are directed to blocks 78 and 80 respectively, and if  
16 the exposure is correct, activity continues at block 92.

17 The operations of blocks 74, 76, 78 and 80 all involve  
18 calculating either a subsequent flash energy or a subsequent set  
19 of camera parameters such as speed and aperture to sample a  
20 corrected amount of light to achieve a correct exposure. The  
21 calculation is either for a subsequent flash or ambient sample  
22 to be analyzed, or a final flash energy level or set of  
23 parameters for a final sample of ambient light to take the  
24 picture. In the case of severe over exposure the operations  
25 indicated by block 74 involve setting parameters to determine  
26 the energy of a second flash when a flash is the light source,  
27 or re-setting the camera parameters such as speed and aperture  
28 if ambient light is the source. For the flash case, block 74  
29 indicates one half of the energy of the first flash, but some  
30 other fraction could be used as well. Similarly, if the  
31 condition is extremely underexposed (low clipping) where nearly  
32 all of the pixel intensities are near the low end of the  
33 intensity scale, parameters are set to direct a second flash at  
34 higher energy (block 76). Although block 76 indicates doubling  
35 the energy, some other factor could be used.

1        If the condition is merely overexposed i.e. over exposed to  
2        a lesser degree and a detailed histogram can be prepared, the  
3        image data is adjusted (block 78) by a scaling factor until the  
4        histogram shows preferably .5% of the intensity data exceeding  
5        a predetermined intensity level, at which point the  
6        corresponding scaling factor is used to scale down the first  
7        flash power, or is used to determine adjusted camera parameters.

8        If the result of the analysis indicates a similar condition  
9        of under exposure to a lesser degree than low clipping so that  
10       a histogram can be created (block 80), the processing is similar  
11       to the description above for overexposure. The scaling factor  
12       for under exposure would be greater than unity, which would  
13       increase the flash energy.

14       If the first flash or ambient light sample results in a  
15       correct exposure 82, the processor proceeds directly to block 92  
16       and the flash is activated at a power level equal to the first  
17       flash energy, or in the case of ambient light, the same quantity  
18       of light is admitted/sampled again.

19       In the above cases involving over exposure 78, under  
20       exposure 80, and correct exposure 82, a second flash or sampling  
21       of ambient light is not required. When the analysis shows  
22       correct exposure, the corresponding flash energy is again  
23       activated or the sampled quantity of ambient/secondary light is  
24       again sampled (block 92), the image grabbed 94 and recorded 96.  
25       In the cases of high clipping 74 and low clipping 76, either a  
26       second flash is activated 84 at an adjusted energy level, or a  
27       second ambient light sample is admitted followed by the grabbing  
28       of the image 86 and further analysis 88 and decision making in  
29       order to arrive at a correct flash energy or setting of camera  
30       parameters. In the preferred embodiment, a maximum of two  
31       flashes occur before a final flash is activated to take the  
32       picture. A larger number of flashes prior to the final flash  
33       are also included in the invention and this is indicated by  
34       arrows 85 and 87 showing the operations from block 70 to 84  
35       repeated. This repetition can be any number of times according

1 to the programming. For example, smaller increments of flash  
2 energy adjustment in blocks 74 and 76 could be used, which could  
3 require more repetitions of analysis and adjustment to arrive at  
4 a useable flash energy from which to scale (block 78, 80) a  
5 final flash energy, or more adjustments of flash energy could be  
6 done before a final determination that the minimum or maximum  
7 flash energy should be used. Following the operation of block  
8 88, determining optimum flash energy or camera parameters, the  
9 light source (flash or ambient/secondary) is activated 98, the  
10 image grabbed 100 and recorded 102. This is all indicated by  
11 block 88, the details of which will be fully described in the  
12 following specification in reference to the figures of the  
13 drawing.

14 The "sample image" block 71 of Fig. 3 is more fully  
15 described with reference to Figs. 4a and 4b. The image optical  
16 pick-up 30, such as a charged coupled device (CCD), contains  
17 thousands of individual receptors, i.e. pixels (picture  
18 elements). An analysis of the output of each of these elements  
19 would be a very expensive project, and for this reason the  
20 pixels are sampled (block 71). For example, suppose there were  
21 300,000 pixels. In order to bring the analysis down to a more  
22 economical level, 1000 of the pixels could be selected from the  
23 300,000. The number of pixels and the following numbers and  
24 graphs are given by way of illustration of the method and  
25 apparatus of the present invention, and are not to be considered  
26 as limiting, since any number of pixels or any sample quantity  
27 could apply. In the example selected for illustration, a  
28 significantly greater number of pixels are sampled from the  
29 center area relative to the edges since the center of the image  
30 usually contains the primary subjects of the photography. This  
31 selective sampling gives greater weight to the lighting of the  
32 more important area of the image. For example, suppose square  
33 104 of Fig. 4 is the total area of an image. For illustration,  
34 it is partitioned into a center region 106 and an edge region  
35 108. The camera can be set up to consider the center region 106

1 as being of greater importance. The area is arbitrarily  
2 selected for illustration to contain 4% of the pixels. The  
3 camera in this case would then weigh light intensity from the  
4 center 106 more heavily than the edge region 108, by sampling a  
5 larger number of pixels per unit area from the center region  
6 than from the edge region. For example, Fig. 4b represents a  
7 weighted sampled image of image 104. The original region 106 is  
8 now represented by region 110 occupying 25% of the total sampled  
9 image and region 108 represented by sampled region 112 in Fig.  
10 4b. In other words, a particular area of the image can be over  
11 sampled in order to weigh it as more important in determining  
12 what is a correct exposure. Although the preferred embodiment  
13 involves sampling the center region more heavily, alternate  
14 embodiments involve sampling more heavily in other areas, or in  
15 more than one selected area.

16 Block 72 of Fig. 3 includes the creation of a histogram and  
17 multiple region bar graph from the sampled image data, and  
18 evaluation of the degree of exposure as high clip, over exposed,  
19 properly exposed, under exposed or low clip. For ease of  
20 wording, the terms over exposed and under exposed will generally  
21 be used to refer to moderate over or moderate under exposure,  
22 and not to include the more severe form of under or over  
23 exposure that places pixels at one or the other extreme of the  
24 intensity scale. These more severe forms are indicated by the  
25 terms low clip and high clip as referred to above, or low  
26 clipping and high clipping, or descriptively as extreme under or  
27 extreme over exposure.

28 For ease of illustration of the histogram and bar graph  
29 process, suppose the grid of 25 pixels in Fig. 5 is the sampled  
30 image intensity data. Also, for simplicity, the light intensity  
31 values are assumed to have the range of 1 to 1000. Each square  
32 114 represents one pixel of the sampled image, and has a number  
33 assigned which is the value of light intensity of the pixel  
34 selected for illustrative purposes. In addition to sampling the  
35 image data, the processor 12 further simplifies and speeds

1 calculations by selecting a predetermined number of regions of  
2 intensity to create a bar graph to aid in the evaluation instead  
3 of evaluating each pixel. For this illustration, suppose the  
4 number of regions of light intensity selected is five, the first  
5 region being the number of pixels with light intensities of 1-2,  
6 the second having values of 3 and 4, the third, 5 and 6, the  
7 fourth 7 and 8 and the fifth, 9 and 10.

8 Fig. 6A shows a histogram, i.e., a plot of pixel quantity  
9 versus light intensity with the original quantity of each light  
10 intensity recorded as small circles. The histogram of  
11 "quantities" of pixels with a given intensity versus "intensity"  
12 is overlaid by the five region bar graph. Region 1 is  
13 represented by bar 116, region 2 by bar 118, region 3 by bar  
14 120, region 4 by bar 122 and region 5 by bar 124. Bar 124 is of  
15 zero height because there are no pixels in the corresponding  
16 intensity range, which is from intensities greater than 800, up  
17 to and including 1000. The height of bar 116 is the number of  
18 pixels having intensities from zero to 200, including one pixel  
19 at intensity 100 and five at intensity 200, for a total of 6  
20 pixels defining the height of the bar. The other bars are  
21 similarly derived. The modified bars 126-134 are outlined by  
22 dashed lines and are the result of the quantity of pixels having  
23 scaled intensity values, the quantities noted by the small x's.  
24 The purpose of the scaling is related to scaling in blocks 78,  
25 80 and 88 for the purpose of arriving at a scaling factor, which  
26 is used to multiply a previous flash to yield a correct final  
27 flash energy. This process will be fully described in the  
28 following discussions of the figures of the drawing. For  
29 example, the first region after intensity scaling has a quantity  
30 of pixels equal to one. The pixel initially had an intensity of  
31 100, which is noted by the "0" identified by item no. 138.  
32 After an analysis which will be fully explained, the intensity  
33 is multiplied by a scaling factor which moves the position of  
34 the quantity notation to the intensity 106.25 indicated by the  
35 "x" and identified by item no. 136, thus shifting its position



1 to the right on the intensity scale. The second "0" indicated  
2 by item no. 140 indicates a quantity of five pixels with  
3 intensity of 200. The scaling shifts this value above the 200  
4 limit of region 1 and into region 2 as noted by the second x  
5 identified by item no. 142. Therefore, the new region 1 has  
6 only one pixel as indicated by the dashed bar 126. A similar  
7 explanation follows for the other regions. Of particular note  
8 is region 5 which begins with no pixels, but due to the scaled  
9 values moving higher in intensity, the dashed/modified region 5  
10 has one pixel. Note also that because a multiplicative scaling  
11 factor was used, the horizontal distance (intensity difference)  
12 between the first "0" and the first "x" is much smaller than the  
13 intensity difference between the last "0" 144 and last "x" 146.  
14 For ease of reference, the quantities of pixels and their  
15 intensities before and after scaling are shown in the table of  
16 Fig. 6B. The above example will be referred to in the following  
17 detailed description of the exposure analysis performed by  
18 blocks 72 and the scaling operations performed in blocks 78, 80  
19 and 88.

20 The "analyze exposure" block 72 of Fig. 3 represents the  
21 creation and analysis of the bar graph of the actual sampled  
22 image intensity data. This analysis can now be more fully  
23 understood through reference to Fig. 7. Block 152 indicates the  
24 input of the sampled image from block 71 of Fig. 3, and blocks  
25 154 and 156 refer to the making of the histogram and bar graph  
26 as explained above in reference to Figs. 5 and 6. According to  
27 block 158, region 1 of the bar graph is evaluated and if it  
28 contains more than a preset high value, the exposure condition  
29 is termed low clipping (block 160). Similarly, in block 162,  
30 region 5 is evaluated and if it contains more than a preset  
31 value of pixels the exposure is termed high clipping (block  
32 164). If neither high or low clipping occur, region 3 is  
33 evaluated (block 166) and if the number of pixels is found to be  
34 within preset upper and lower limits, the exposure is termed to  
35 be "ok" (block 168). Otherwise, if region 3 has a high number

1 of pixels exceeding the upper limits, region 2 is evaluated  
2 (block 170). If it has a low number of pixels, the exposure is  
3 "ok" (block 172); and if not, the condition is overexposed  
4 (block 174). If the region 3 (block 166) analysis shows the  
5 number of pixels below the low limit, region 4 is evaluated for  
6 a high number of pixels (block 176). If it has a high number  
7 above a preset level, the exposure is "ok" (block 178).  
8 Otherwise, the condition is underexposed (block 180).

9 If the analysis indicates that nearly all the pixels have  
10 intensities in region 1, the exposure is termed "low clipping"  
11 or "low clip". If nearly all of the pixels have intensity in  
12 region 5, this would be high clipping (high clip). If neither  
13 low or high clipping exists, the analysis proceeds to blocks 78  
14 or 80 in Fig. 3. Referring again to the simplified example of  
15 Figs. 5 and 6, and to Fig. 8, the scaling operations performed  
16 in blocks 78 and 80 can be more fully understood. The solid  
17 line bar graph of Fig. 6A is evaluated according to block 72  
18 explained above, and the condition would be noted as under  
19 exposed. A vertical line 148 (Fig. 6A) is marked showing the  
20 location of a value S equal to 850. S represents a point on a  
21 curve of "input light intensity" versus "output" of the image  
22 optical pickup 30 (curve not shown) where the curve becomes  
23 nonlinear, i.e. where the pickup begins to saturate, a condition  
24 indicative of excessive light input. A value "C" is also noted  
25 in Fig. 6A, marked with a line 150 as the value 800. The value  
26 "C" is supposed to be the point on the distribution of pixel  
27 intensities above which lie .5% of the pixels. This point is  
28 not clear in Fig. 6A because there are only 25 total pixels and  
29 .5% is less than one. For illustrative purposes, it is placed  
30 on the value 800 which includes the pixel of greatest intensity.  
31 According to a preferred embodiment of the present invention, a  
32 scaling factor  $S/C$  is defined, where S is as defined above, and  
33 C is the above defined value for a given distribution of  
34 unscaled pixels. The factor  $S/C$  is estimated by the processor  
35 12 and used in the cases of blocks 78 and 80 to either multiply

1 the first flash energy to obtain an estimated final flash energy  
2 for acceptable exposure, or to adjust the camera parameters if  
3 ambient light is the source. For example, in Fig. 6A, the ratio  
4 of  $S/C = 850/800 = 1.0625$ . For reference, Fig. 6B is a table  
5 giving the quantities and intensities before and after scaling  
6 for Fig. 6A. Multiplying a first flash energy by the factor  $S/C$   
7 and activating the flash would result in a pixel intensity  
8 distribution as shown by the "x"'s in Fig. 6A, with a bar graph  
9 as indicated by the dashed lines. Note that the dashed lines  
10 are displaced horizontally from the solid lines so they can be  
11 seen, but in fact they are horizontally representative of the  
12 same intensity. Also note that the scaled plot has a pixel at  
13 the value  $S$  equal to 850. A more realistic distribution of  
14 pixels might be more instructive at this point, and such a  
15 distribution is shown in Fig. 8. The solid curve "H" represents  
16 an original distribution resulting from a first flash. The  
17 point "C" at intensity 700 is supposed to represent the  
18 intensity point above which .5% of the pixels lie. The dashed  
19 curve "H" represents the plot of the scaled intensities which  
20 should result if the pixels represented by the solid curve H are  
21 multiplied by the factor  $S/C$ . In the case of Fig. 8, the value  
22 of  $S/C$  is  $S/C = 850/700$ . Note the area above  $S = 850$  in the  
23 dashed curve. It should represent .5% of the total number of  
24 pixels. A reverse process with an  $S/C$  less than unity would  
25 result if the point C were initially above the point S, i.e.  $S/C$   
26  $< 1$ .

27 The scaling processes of blocks 78 and 80 are illustrated  
28 in block form in Fig. 9. Block 182 indicates the need for the  
29 histogram of the sampled image from block 72. Block 184  
30 describes the need of the value  $S$ . Block 186 includes the  
31 operation of finding the point C on the histogram, above which  
32 .5% of the pixels lie. Block 188 gives the ratio of  $S/C$  as the  
33 scaling factor.

34 Referring now to Figs. 10 and 11, the operations performed  
35 according to the "activate light source" blocks 92 and 84 can be

1 more fully understood in the case when the flash is used. Block  
2 190 defines the inputs required. These are the desired flash  
3 energy " $E_{\text{flash}}$ ", the voltage on the flash capacitor " $V_i$ ", and the  
4 value of the flash capacitor " $C$ ". The capacitance " $C$ " of the  
5 flash capacitor is a constant, and is a predetermined, pre-  
6 programmed value. The desired flash energy " $E_{\text{flash}}$ " is determined  
7 as described in relation to blocks 78 or 80, depending on  
8 whether the result of the first flash was a condition of over or  
9 under exposure, and is  $E_{\text{flash}} = S/C (E_1)$  where  $E_1$  is the previous  
10 flash.  $E_1$  is the energy of the first flash for the activate  
11 blocks 92 and 84. The determination of  $S/C$  was explained above  
12 for blocks 78 and 80. When a correct exposure condition is the  
13 result of the first flash, the value of  $S/C$  is unity.

14 In the case where high or low clipping results from first  
15 flash or a first sampled ambient light, the scaling procedure of  
16 blocks 92 and 84 is not used. In these cases the scaling factor  
17 is a predetermined setting for flash operation, either 1/2 for  
18 high clipping or 2 for low clipping as indicated in blocks 74  
19 and 76, although other values are included in the spirit of the  
20 invention. The activate flash blocks 92 and 84 also define the  
21 operation of sensing the voltage  $V_i$  prior to a flash.

22 With the above discussed values of  $E_{\text{flash}}$ ,  $V_i$  and  $C$ , the  
23 processor 12 performs the calculation indicated in block 192 of  
24 Fig. 10 for  $V_c$ .  $V_c$  is the value of the flash capacitor voltage  
25 at which point the desired flash energy is expended in the flash  
26 unit. Solving the equation yields

$$V_c = \frac{2}{C} \sqrt{\frac{1}{2} C V_i^2 - E_{\text{slash}}}$$

29 The flash operation described above is more fully explained  
30 in reference to Fig. 11. The figure shows a capacitor 194,  
31 switch 196 and flash bulb 198 arrangement. The voltage V across  
32 the capacitor terminals 200 and 202 is monitored. The value of  
33  $V_i$  prior to a flash, as described above is measured and used in  
34 the calculation of a lesser value of voltage  $V_c$  at which point  
35 the capacitor 194 will have discharged the desired amount of

1 energy to the flash bulb 198. The transfer of energy from the  
2 capacitor 194 to bulb 198 begins when a signal on line 204  
3 causes switch 196 to connect line 200 to line 206 to the bulb  
4 198. When the voltage between lines 200 and 202 (across  
5 capacitor 194) is sensed to be equal to  $V_c$ , a second signal is  
6 applied on line 204 causing switch 196 to disconnect line 200  
7 from line 206.

8 Referring to Fig. 12, there is shown a block diagram  
9 detailing the operations indicated by the second exposure  
10 analysis block 88 of Fig. 3. As discussed in reference to Fig.  
11 3, if the exposure resulting from the first flash or first  
12 ambient light sample is either high or low clipping, a second  
13 flash or second ambient light sampling is performed of either  
14 lower or higher energy respectively for the flash, or adjusted  
15 parameters for the ambient light. This flash or sampling,  
16 described above in reference to block 84, provides an adjusted  
17 light to grab an image (block 86) which is analyzed according to  
18 block 88.

19 According to Fig. 12, the grabbed image (block 86, Fig. 3)  
20 is passed as indicated by arrow 208, and is sampled (block 210)  
21 and then examined according to the "analyze exposure" block 212.  
22 Blocks 210 and 212 define the same operations on the image data  
23 of the second flash or second sample as blocks 71 and 72 perform  
24 on the image data from the first flash or first sample.  
25 Similarly, if the result of the analysis is a determination that  
26 the exposure is correct, the sequence of activities defined by  
27 blocks 214-220 is identical to that of blocks 92-96 of Fig. 3.  
28 This is in response to a correct exposure resulting from the  
29 first flash or first ambient light sample. The additional block  
30 220 indicates the option of supplying a notice to the operator  
31 that the exposure is okay. This notice can be in any of a  
32 variety of forms known to those skilled in the art, such as a  
33 light bulb of any color, or LED read out, etc. In the event the  
34 second flash results in low clipping (224), the processor 12  
35 sets the flash to a maximum intensity as indicated by block 226.

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1 The flash or sample is then activated (block 228), the image is  
2 grabbed 230 and recorded 232. Similarly, if the second flash or  
3 second sample yields a high clip condition 234, the processor 12  
4 directs the flash to a minimum (236). In the case where the  
5 light source was ambient light, the parameters are set for  
6 minimum light. The flash or sampling is then activated (228),  
7 the image grabbed (block 230) and recorded (232).

8 If the result of the second flash or second ambient sample  
9 is a condition of under exposure (238) meaning a condition not  
10 severe enough to be low clipping, and if the result of the first  
11 flash (240) or first sampling is under exposure 242, the second  
12 flash or sampling is scaled with a scaling factor S/C as  
13 indicated by block 244. The process of determining the scale  
14 factor S/C is the same as that described above in reference to  
15 block 80 of Fig. 3. The flash or sampling is then activated  
16 (228). In the case of a flash, the energy is set to a level  
17 equal to  $E_2(S/C)$  where  $E_2$  is the second flash energy and S/C is  
18 the scaling factor. In the case of ambient light, the  
19 parameters of the last sampling are scaled to adjusted  
20 parameters using the factor S/C and an optional look-up table.  
21 The image is then grabbed 230 and recorded 232. Similarly, if  
22 the first result is "over exposure" (246), the preferred  
23 embodiment simply scales the second flash energy level or the  
24 camera parameters for ambient light (block 248) by determining  
25 the scale factor S/C. The determination of the scale factor S/C  
26 is again done in the same way as that described in relation to  
27 block 80 of Fig. 3.

28 In the case where the analysis of the sampled image of the  
29 second flash results in a condition of over exposure (250), and  
30 the result of the first flash (252) is under exposure (254), the  
31 second flash energy is scaled by the value S/C (block 248) to  
32 obtain the final flash energy. Also, if the first flash is over  
33 exposed (256), the second flash energy is again scaled (block  
34 258) by the value S/C for final flash energy. Similarly for an  
35 ambient light source, the camera parameters are scaled from the

parameters used in the second light sampling. The scaling operations in blocks 244, 248 and 258 are all similar to the scaling operations of blocks 78 and 80 as described in reference to Fig. 3. The only difference is that the scaling blocks of Fig. 12 scale the second flash energy or second camera parameters rather than the first. Also, it should be pointed out that scaling the second flash energy/parameter is done for simplicity in the cases where the second exposure image is under exposed and the first image is over exposed (ref. 238 and 246), and the case when the second image is over exposed and the first is under exposed (refs. 250 and 254). Alternate embodiments of the invention include exposure methods of scaling in block 248 when the first and second exposure bracket the correct exposure. For example, in the case where the first exposure results in under exposure and the second results in over exposure, a weighted average could be used. For the flash case, an example could be to assume a final flash energy  $E_w = A(E_2 - E_1) + E_1$  where A is a preset fraction between zero and one, the selected value depending on the estimated accuracy of the second flash. For example, it would normally be assumed that the second flash energy is closer to correct than the first and a choice of  $A = .7$  might be selected. Other weighted averages are also included in the spirit of the present invention.

24           The "Notice" blocks 260-268 define an optional visual or  
25   recorded message to the operator of the particular exposure  
26   condition existing when a picture is taken.

27        Although a preferred embodiment of the present invention  
28        has been described above, it will be appreciated that certain  
29        alterations or modifications thereon will be apparent to those  
30        skilled in the art. It is therefore that the appended claims be  
31        interpreted as covering all such alterations and modifications  
32        that fall within the true spirit and scope of the invention.

34 What is claimed is: